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SEARCH FOR CHARM PRODUCTION IN 400 GeV/c PROTON INTERACTIONS

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Introduction

The current upper limit on the hadronic production of D's at Fermilab has been set by the FNAL-Michigan-Purdue(FMP) group which has set a limit of $\sigma B \simeq 500$ nb for $D^0 \to K\pi$ in a double arm spectrometer. We propose here a simple modification of the FMP experiment which will increase the sensitivity by an order of magnitude. This extra order of magnitude in the cross section limit is in a region where it would be especially surprising if the D^0 did not appear.

The basic limitation in searching for charmed objects produced in hadronic channels has been the high background level from normal strong interaction sources. We propose here to apply an additional constraint on the selection of events which substantially enhances the signal to background ratio. Specifically we search for production of the D^{*-}. Although the Q-value for the decay $D^{*\pm} \to D^0\pi^\pm$ has not been directly measured the best estimate to date is 4.5 ± 3.5 MeV(1). In the limit of zero Q-value the pion has the same velocity as the D^0 in the laboratory. The double arm spectrometer intrinsically selects D^0's within a restricted momenta interval. Thus the pions accompanying the D^0's from D* decay, are well collimated and have a central momentum of $\frac{M_\pi}{M_D} P_D$. Detailed off-line reconstruction permits a measurement of the Q-value of the D* decay to about ± 1 MeV!

We have performed this experiment at BNL using 10.5 GeV/c pions. The limit achieved there for σB is 50 nb(4σ effect) for the reaction.

$$\begin{array}{l} \pi^- + p \to D^{*-} + \Lambda_c^+ \\ \qquad\qquad\quad \hookrightarrow \pi^- + \bar{D}^0 \\ \qquad\qquad\qquad\qquad \hookrightarrow K^+ + \pi^- \end{array} \qquad (1)$$

In the BNL experiment the requirement of the extra pion in the trigger reduced the trigger rate by a factor of 30. Reconstruction reduced the background another factor of 6 for a total reduction in background of 180. Superior momentum analysis of the soft pion, proposed in this experiment, should permit additional off-line discrimination against background of perhaps another factor of 5, leading to an overall background suppression of 1000. To make the extrapolation from BNL to Fermilab energies we have assumed that the production of background follows the usual scaling laws.

Countering the substantial decrease in background is a suppression in signal which arises from losses in the competing D* decay channels of $\gamma + D^-$ and $\pi^0 + D^-$. If the Q-value for $D^{*-} \rightarrow D^0 + \pi^-$ is a few MeV, this loss should however not exceed a factor of 2.[2] With the background reduced by almost $\sim$1000 and the signal reduced by $\sim$2, the net gain in the ratio of signal to background is expected to be about 500. This accounts for more than an order of magnitude improvement in the estimated σB limit. Of course, here we measure σ for the production of D* as opposed to D^0.[3]

We envision doing the experiment using the FMP double arm spectrometer recently removed from the Meson area. An additional magnet in the target region of the experiment is used to analyze the soft pions. We propose that this 3-arm spectrometer be installed in the low-halo experimental area in Proton West. Using a transmission target with 10^7 interactions/pulse a σB limit of 50 nb could be obtained for the production of D^{*-} with 100 hours of data taking. Correspondingly, we initially request 500 hours of running time to perform this measurement.

The Spectrometer

The spectrometer configuration which we propose to utilize is shown in detail in figure 1 (a & b). We intend using a double arm spectrometer system located at near 90^0 in the cm system to detect the $K\pi$ from the D^0 decay and a third magnetic spectrometer arm to momentum analyze the accompanying slow pion. In the figure we have shown the (FMP) double arm spectrometer positioned in the Proton West area. The primary features of this apparatus have been documented in reference (4) and are good invariant mass resolution ($\sigma \sim 5$ MeV) and good particle identification for π, K, and proton in the momentum range 7-21 GeV/c. The third spectrometer magnet is located two meters downstream of the target along with a set of trigger hodoscopes and MWPC's. This magnet would have a minimum aperture of 36" vertically x 30" horizontally run with a $p_\perp$ of 400 MeV/c. (Possible candidates for this third magnet exist at BNL (48D48) and at ANL (SCM-104).)

The MWPC's for this third arm remain to be constructed, however their design specifications ($\sim$ .5m x 1m active area, 3-4mm wire spacing) are standard, and their implementation poses no significant problem to the early mounting of this effort. The total number of wires contained in this third arm is $\lesssim$ 2000. It is stressed that the third arm accepts <u>all</u> slow pions from the cascade decay of the D^{*-} where $D^0 \to K\pi$ enters the double arm spectrometer. With the position resolution in the third spectrometer arm we achieve a resolution in the Q value of $\sigma \sim 1$ MeV.

The Beam, Trigger Rates and Cross Section Circuits

We propose to install the 3 arm spectrometer in the 50' x 50' experimental hall in Proton West. This area is adequate for a number of reasons. (1) The primary beam in this area is nearly halo free giving a very clean experimental environment which is imperative for our proposed interaction rate of 10^7/pulse. (2) The beam spot at the center of the target hall is approximately 4.5mm horizontally and 0.5mm vertically which is small enough to eliminate the need for particle tracking very near the $\sim$ point target (a necessity at these interaction rates) while still preserving sufficient position accuracy to achieve $\sigma_Q \sim 1$ MeV. Due to space limitations in this hall it is necessary to target the primary protons 25' further upstream at the entrance to the experimental area, perhaps necessitating some minor changes in quadrupole positioning, in order to maintain the present spot size at the target.

The target will be a transmission target of a reasonably light nuclear material (Be) of an appropriate length ($\sim$ 5mm) to yield an interaction rate of $10^7/10^{10}$ incident protons. The transverse dimensions of the target would remain small ($\sim$ .5mm) in order to allow for use of the target point in the off-line reconstruction. The vacuum chamber surrounding the target area must be reconstructed to minimize the effects of Coulomb scattering on the outgoing particles in all three areas. One possible approach would be to use a thin wall corrugated vacuum pipe arrangement or a more straight forward target box with three exit windows.

Based on the data of Ref. 4 we would expect 800 di-hadron events/10^7 interacting protons with both laboratory momenta greater than 7 GeV/c. In the FMP setup the chambers closest to the target survive in the environment produced by 10^7 interactions/pulse. Based on our present experiment at BNL and scaling the particle production cross section to FNAL energies we estimate that $\sim$ x30 suppression factor can be achieved in this trigger rate through the extra requirement of the slow pion. This brings the trigger rate down to $\sim 30/10^7$ interactions. This overall suppression can be further increased through the off-line analysis by another factor of 35 based on present data and the improved angular resolution of the proposed spectrometer. This yields a total suppression factor of ~ 1000 over ordinary hadronic $K\pi$ events.

The corresponding sensitivity we thus hope to reach in 100 hours of running at 10^7 interactions/pulse is $\sigma B = 50$ nb for $M_{K\pi} = 1.86$ GeV. For this calculation we have folded in the spectrometer acceptance of 3×10^{-5} at this mass, determined by our Monte Carlo simulation.

Resources and Scheduling

A large portion of the equipment which we propose to use has already been utilized in a similar endeavor, hence we anticipate no unusual problems with resurrecting this equipment. It has been noted that the only new pieces of equipment needed to perform this experiment are a rather modest MWPC system and several new hodoscope counters. Such a system can be assembled in our own laboratory and ready to install in May or June of this year (1977). The vacuum chamber construction and magnet loan have not been formally worked out. However, we see no major obstacle with regard to either of these areas if the experiment is approved.

Considering the high topical interest in these experimental results and the relatively modest effort in mounting the experiment we urge its prompt scheduling. We are confident that we could begin installation as early as May of this year. This early installation would enable us to take some data before the shutdown in this area for work on the 1 TeV transport downstream.

We request 100 hours of beam for tune-up and testing and 400 hours of 400 GeV/c operation at 10^{10} protons/pulse for data taking.

References

1. G. Goldhaber, private communication.

2. From SPEAR it is known that $\Gamma(D^{*0} \rightarrow \gamma + D^0)/\Gamma(D^{*0} \rightarrow \text{all})$ is about 0.4. The Q-value for $D^{*0} \rightarrow \pi^0 + D^0$ is 2 to 4 MeV.

3. The ratio of the cross sections for D^* and D^0 production is large at SPEAR for reasons not entirely known. One cannot expect the same mechanisms to hold in hadron production. Given the small mass difference between D's and D*'s, it is reasonable to assume that they will be produced in comparable amounts at Fermilab energies.

4. D. Bintinger <u>et.al.</u>, Phys. Rev. Lett. <u>37</u>, 732 (1976).

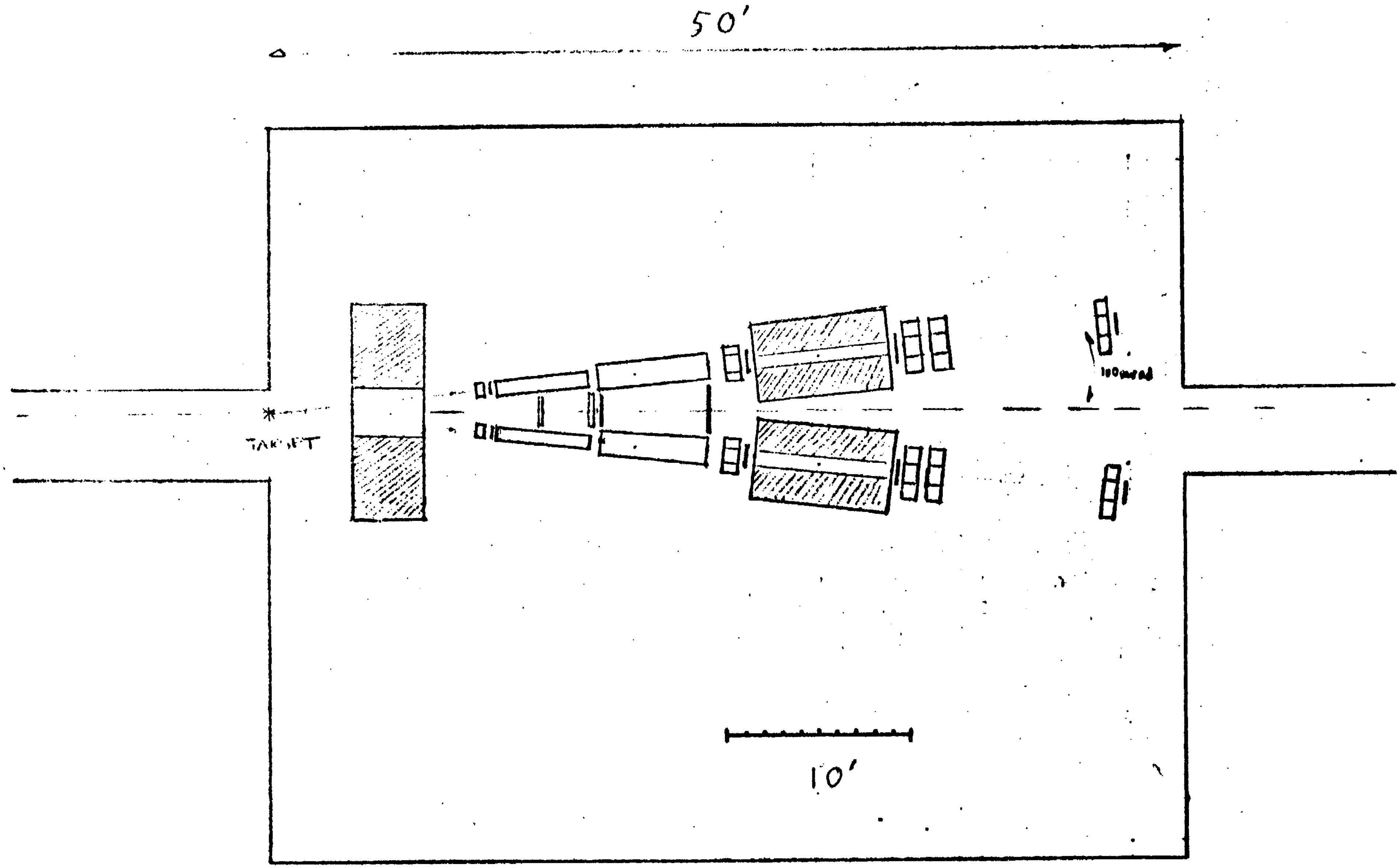

FIG. 1(a)